Is Seeing Believing? The Effects of Virtual Reality on Young, UK Children's Understanding of Possibility and Impossibility

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This study explored the effects of virtual reality on young children's understanding of possibility and impossibility. It involved four-year-old children (30 boys and 30 girls) who were randomly allocated to a virtual reality group, a video group, or a picture book group. Each child was individually presented with three impossible and three matched possible events using their assigned medium. After each event, children were asked whether it was possible in real life and why/why not. Children in the VR group were more likely to correctly judge the possibility of possible events than children in the video group and they were more likely to incorrectly judge the possibility of impossible events than children in the video group. Furthermore, they were more likely to correctly judge the possibility of possible events than impossible events. The results suggest that virtual reality affects four-year-old children's understanding of possibility and impossibility. Practical implications of these findings are discussed.

Keywords: Virtual reality; Google Cardboard; media richness; immersive technology; children; cognitive development; fantasy; possibility; reality judgments.

Introduction

Preschool-aged children most commonly use storybooks and two-dimensional screens (i.e. television, tablets and smartphones) for learning and entertainment although their use of relatively low-immersive mobile Virtual Reality (VR) devices, like Google Cardboard, is predicted to increase in coming years (Bailey & Bailenson, 2017). This new information communication technology immerses its users in three-dimensional computer-simulated virtual worlds via a mobile head-mounted display, allowing individuals to look in any direction at any time and have limited interactions with virtual content (Bailey & Bailenson, 2017). A considerable amount of research has examined the effect of VR on adults' thoughts, behaviours, and attitudes. However, little research has been performed to explore the impact of VR on young children. Given the predicted growth of VR in children's lives (Bailey & Bailenson, 2017), it is important that we investigate its impact on their behaviour and development. The aim of the current study is therefore to explore the effect of VR on children's judgments of possibility and impossibility.

Children's use of VR has a number of possible benefits. On one hand, it enables children to visit realistic or fictional locations and encourages them to broaden their minds as well as imagination. On the other hand, it has the potential to change how children learn from media, because it is both motivating and engaging while enhancing situated learning and facilitating the transfer of knowledge to the real world (Dede 2009). For example, VR has been successfully used to teach the consequences of climate change by allowing children to experience an immersive underwater world, which was designed to demonstrate the process and effects of rising seawater acidity (Markowitz, Laha, Perone, Pea, & Bailenson,, 2018). Recent reviews confirm the potential of VR for supporting children's learning (Jensen, & Konradsen 2018; Queiroz, Nascimento, Tori & da Silva 2018). VR has also been used to reduce children's emotional and physical pain during medical operations (Aminabadi, Erfanparast, Sohrabi, Oskouei, & Naghili, 2012; Atzori, Hoffman, Vagnoli, Messeri, & Grotto 2019) and as an assessment tool for diagnosing Autism and ADHD (Bellani, Fornasari, Chittaro, & Brambilla, 2011; Gilboa, Fogel-Grinvald & Chevignard, 2018; Pollak et al., 2009). However, a number of concerns have been raised regarding young children's use of VR, for example, as children's media often include impossible events, which defy the laws of physics and biology (Woolley & Ghossainy, 2013). While many researchers argue that by age four, children are capable of making reliable possibility judgments (i.e. determine whether possible or impossible events can occur in real life or not) (Shtulman & Carey, 2007; Woolley & Ghossainey, 2013), others argue that VR could distort their evaluative judgment of reality and fantasy (Bailey & Bailenson, 2017).

Media Richness Theory has been used to explain the differing effects of media on children's understanding (Segovia & Bailenson, 2009). This theory hypothesises that the more information a medium is able to convey, particularly in relation to an ambiguous topic, the more convincing it will be (Daft & Lengel, 1986). Indeed, rich media, like VR, provide a personal focus (i.e. make the individual feel like they are at the centre of the experience), immediate feedback (i.e. rendering a dynamic location-specific perspective within a headset), transmit multiple cues (i.e. audio, visual), and can include natural language (i.e. speech, gestures), which makes them more effective in communicating information than lean media using few cues (Daft & Lengel, 1986; see Table 1). Therefore, as rich media convey information by using similar cues to real life (see Table 1), pre-school children are likely to experience a strong belief towards them due to investing little cognitive effort to reflect on their legitimacy (Bailey & Bailenson, 2017).

Slater and Usoh (1993) suggest that VR's richness is largely dependent on a sense of presence, which can be defined as "the perceptual illusion of nonmediation" (Lombard & Ditton 1997). Presence is also commonly described as the sensation of 'being there' in a virtual space (Biocca, 1997). Slater and Usoh (1993) suggest that the brain's higher cognitive centres process visual and proprioceptive information (i.e. body position and movement) in VR similarly to the real world, which fools the brain into believing that VR is real. Furthermore, research with adults and children has revealed that the brain responds to VR as if it were real (Bohil, Alicea, & Biocca, 2011; Hoffman et al., 2006). The sense of presence, promoted by VR, also encourages users to self-reference, as individuals feel like their body exists in the virtual world and everything that occurs within it is related to the self. Consequently, they process and encode more features of a VR experience compared to more passive experiences of the same events in traditional media (Bailey & Bailenson, 2017). Based on the above theory and evidence, VR may lead young children to belief that all presented events are possible. For example, children might forget that they are wearing a head-mounted display in VR or might not realise that its content is computer-generated and, thus, not real. In contrast, pre-school children are more likely to correctly judge events presented in lean media, like books, as they do not attempt to distort children's perception of reality (Segovia & Bailenson, 2009).

Recent research supports this view. Shtulman and Carey (2007) reported that four-year-olds correctly judged the reality status of 91% of possible and 93% of impossible events in a picture book. Furthermore, Li, Boguszewski and Lillard (2015) demonstrated that four-year-olds correctly judged the possibility of only 55% of impossible events, which were presented as videos (moderately rich media) from a Chinese television show. In both studies, four-year-olds provided mainly hypothetical and redundant justifications, which imply that young children may be susceptible to believe richer media due to basing their judgments on intuition over factual knowledge. In addition, Segovia and Bailenson (2009) reported that children perceive rich media as more realistic than lean media. The researchers verbally suggested to preschool and primary school children that they had experienced one of two impossible events in the past. The study had four conditions: (i) an idle condition, where children sat still for a minute; (ii) a mental imagery condition, where children had to imagine the event; (iii) a VR condition, where they saw another child performing the event (VR-other) and (iv) a VR condition, where they saw themselves performing the event (VR-self). Although the latter condition was unusual, as VR experiences typically do not allow the user to observe him/herself, primary school children developed significantly more false memories in VR-self and mental imagery conditions, which are both rich media (see Table 1), compared to the idle group. Indeed, four out of seven children in each condition developed at least one false memory. These findings suggest that rich media, like VR, encourage children to develop false memories and believe in the impossible, whereas lean media do not have the same manipulative effect.

Unfortunately, the above research has a number of limitations. Firstly, VR research in the field has used small samples (Segovia & Bailenson, 2009), which limited the robustness of its findings. Secondly, no studies exist that specifically investigate the effects of mobile VR on young children's possibility judgments (Bailey & Bailenson, 2017). Thirdly, no study has directly compared the effects of different media in relation to children's understanding of reality and fantasy. Therefore, existing research does not explain if and how mobile VR differs from traditional media in its impact on young children's understanding of possibility.

In light of the above limitations, the current study compared the effects of a picture book, videos, and VR on four-year-old children's possibility judgments. It was hypothesised that children will be more likely to incorrectly judge the possibility of impossible events with increasing media richness. Hence, children will provide more incorrect judgments of impossible events when using VR compared to videos and a picture book..

Method

Design

The study used a two-way mixed design. The within-participants independent variable was the event type: possible events and impossible events. The between-participants independent variable was the medium: VR, videos, and picture book. The dependent variable was the participant's possibility judgments, which had two levels: correct and incorrect.

Participants

Four year-old children (30 girls and 30 boys) were recruited from a large suburban preschool in the North West of England via opportunity sampling and were allocated to one of three media groups, controlled for sex and age.

(1) VR group

(2) Video group

(3) Picture book group

The majority of the children were White British, Somali, Arabic and Pakistani. All children were born and raised in the UK, spoke English at home, and were primarily from a lower socio-economic background. None of the children had experienced VR before the study. Children who suffered from photosensitivity, epilepsy, vision abnormalities, psychiatric disorders and/or heart or other medical conditions were excluded from participation to avoid adverse effects from media exposure.

Apparatus

The VR group was presented with a Google Cardboard head-mounted display, which was fitted with an adjustable headband and foam boarder. A Samsung Galaxy S5 mobile phone was placed in the apparatus and was used to play the event videos, which the experimenter had previously uploaded to YouTube.

For the Video group, a MacBook Air laptop was used to present videos on a 13-inch monitor. The laptop was mounted 24-28 inches away from the children on a table with the monitor's top frame being at children's eye-level.

Finally, the picture book group was presented with an 8.5" x 11" book. It consisted of an introductory page and one page per event. Each page included a photo of the main event, taken from a corresponding video, as well as a written event narrative, which was consistent with previous research (Shtulman & Carey, 2007).

Materials

All three media groups were presented with the same six events. Three impossible events (two men float in the air; a boy changes the colour of a painting with a feather; a girl freezes two men with a light projector) were adapted from Li and colleagues' (2015) study, as they resulted in the highest number of incorrect judgments by their participants (H. Li, personal communication, May 7, 2017). Three possible versions (two men hold on to a pull-up bar; a boy paints over a painting; a girl makes two men cover their eyes with a light projector) were matched to the impossible events. All events were controlled for content, length, animation, characters, background and authenticity to allow for within-group comparisons between possible and impossible events.

Computer-generated VR and laptop videos with display resolutions of 3840 x 2160-pixel and 1920 x 1080-pixel respectively were rendered with a frame rate of 30fps from the same content, created with Unreal Engine 4.15, Mixamo, and Adobe Fuse software. The virtual environment in which all events took place was a template from the Unreal Engine store, featuring a living room, and was chosen as it offered a familiar and friendly scene. An introductory picture book page and two-minute introductory VR and laptop videos presented the room to the children without characters. In each of the six event videos, characters stood still for the first 20 seconds. The central event then followed, lasting 15 seconds. In order to standardise between groups, the picture book included 15-second audio recordings of event narratives.

To control for systematic differences between and within conditions, the viewpoint from which videos/pictures were shown was above the sofa's sitting area within the virtual living room at eye level of a seated small child (see Figure 1). This viewpoint ensured that children in the VR group did not perceive a drastic mismatch between their height in the real world compared to the virtual world to avoid confusion and to make the experience more authentic.

Procedure

Once parental consent was obtained, each child was asked if they felt well and wanted to play a game to help the researcher answer some questions. Children were informed of the voluntary nature of the study/game and their right to ask questions and withdraw at any time. All the children were tested individually in their preschool's activities room and were seated next to the same single researcher at a small table to ensure consistency in experimenter characteristics. The setting was chosen to encourage productive answers whilst minimizing the risk of children interpreting the task as a test. A supervising staff member was always present to ensure that children felt safe and comfortable.

The researcher explained the study procedure to children and introduced one of the three media. Children were reminded that their answers should be expressed verbally and clearly and they were given the opportunity to ask questions. The two-minute introductory phase followed during which children were asked to explain what they saw in the video/picture to establish rapport. During this phase, children also played a short game, which involved finding seven hidden orange plants in the video/picture for familiarisation with the virtual environment.

In the experimental phase, the children were presented with the main events. The order of these events was counterbalanced to prevent response biases and practice effects. Therefore, the three media groups were equally split into five sub-groups, which were presented with one of five orders of events. All sub-groups consisted of a younger (4yrs 0-6 months old) and older boy and girl (4yrs 7-12 months old) to control for effects of age and sex. During the first 20 seconds of each event presentation, the researcher asked the children to point at an orange lamp in the scene and the people next to it to ensure that participants focused on the central event by the time it started to play. Afterwards, the children were instructed to pull off the headset or close the book/laptop.

In line with Shtulman and Carey’s (2007) interview schedule, children were asked to describe the central event to ensure that they had perceived it correctly. If they only described parts or irrelevant aspects (i.e. that looked funny), the presentation was repeated once. If the children did not give a correct description after that, the researcher explained the event. Children were then asked whether they thought it was possible in real life and why/why not. Probing was avoided to reduce the interview's length whilst maintaining a standard protocol across children with differing verbal abilities (Shtulman & Carey, 2007). The experiment would have been terminated if children expressed discomfort or unwillingness to continue, although this did not occur. At the end of the experiment, the researcher corrected children's misconceptions in relation to the events' possibility, explaining what could and could not happen and why/why not. Parents were sent an electronic debrief-form and those wishing to receive more information on the findings were sent a brief summary.

Coding Justifications

Participants provided 474 justifications and themes were generated and grouped into five types (see Table 2), consistent with previous research (Shtulman & Carey, 2007; Li et al., 2015). The researcher and an assistant independently coded 30% of randomly selected justifications with an inter-rater reliability of 93% (Cohen's kappa= .90). The frequency of each justification type was analysed across the media.

Ethics

The study received ethical approval from the University of Bath, Department of Psychology Ethics Committee (Ethics code 17-122). The participants' parents were provided with an information sheet, which outlined the potential harmful effects of VR and what procedures were in place to mitigate risks. After they had read the information, they were asked to sign and return an attached consent form if they wished their child to participate in the study. Previous research has found that children tend to enjoy a short VR exposure (Bailey et al., 2019, Kozulin et al., 2009) and the children in this study similarly appeared to enjoy the experience with minimal physical and emotional distress.

Results

Table 3 shows the mean number of correct possibility judgments for possible and impossible events. A one-way between participants ANOVA was conducted to compare the effects of VR, videos and a picture book on children's possibility judgments for possible events. The data violated the assumption of homogeneity of variance and therefore a Welch F-test and corresponding post-hoc Games-Howell test were used. There was a statistically significant difference between media in terms of the children's possibility judgments for possible events (*Welch's F* (2, 37.16) = 5.43, $p = .009$, $\eta^2 = .15$). Post-hoc contrasts revealed that children in the VR-group judged possible events correctly significantly more often compared to video ($p = .009$) but not picture book groups ($p = .114$). There was no statistically significant difference between picture book and video groups ($p = .463$). A one-sample *t*-test, performed on each media group for possible events, showed that the mean number of children's correct possibility judgments in the picture book ($M_{Diff} = .30$, 95% CI [-.22, .82], $t(19) = 1.21$, $p = .240$, $d = .27$) and video groups ($M_{Diff} = -.15$, 95% CI [-.74, .44], $t(19) = -.53$, $p = .603$, $d = .12$) did not significantly differ from chance-level. However, children in the VR group gave significantly more correct judgments than would be expected at chance-level ($M_{Diff} = .95$, 95% CI [.53, 1.37], $t\ (19) = 4.79$, $p < .0005$, $d = 1.07$).

We also compared the effect of VR, video and picture book media on children's possibility judgments for impossible events using a one-way between participants ANOVA (see Table 3). There was a statistically significant difference between media in terms of the children's possibility judgments for impossible events ($F\ (2, 57) = 4.46$, $p = .016$, $\eta^2 = .14$). Post-hoc contrasts using Tukey HSD revealed that children who used VR judged impossible events as possible significantly more often than children in the video group ($p = .016$). However, the picture book group did not significantly differ in the mean number of correct possibility judgments compared to VR (p = .084) and video groups (p = .776). Three one-sample t-tests were used to investigate whether children's possibility judgments of impossible events differed from chance within each medium. Children in the picture book (M_{Diff} = .15, 95% CI [-.40, .70], t (19) = .57, p = .577, d = .13) and video groups (M_{Diff} = .40, 95% CI [-.15, .95], t (19) = 1.54, p = .141, d = .34) made their possibility judgments at chance-level. However, the VR group made significantly more incorrect judgments than would be expected at chance-level (M_{Diff} = -.65, 95% CI [-1.18, -.12], t (19) = -2.56, p = .019, d = .57).

A related t-test was used to compare the mean number of correct possibility judgments for possible events with impossible events for each type of media. Children in the VR-group judged possible events correctly significantly more often than impossible events (M_{Diff} = 1.60, 95% CI [.68, 2.52], t (19) = 3.66, p = .002, η^2 = .41). However, there were no statistically significant differences between impossible and possible events for the picture book (M_{Diff} = .15, 95% CI [-.85, 1.15], t (19) = .31, p = .757, η^2 = .01) and video groups (M_{Diff} = -.55, 95% CI [-1.62, .52], t (19) = -1.08, p = .295, η^2 = .06).

We also investigated the effects of media on children's justifications. There were no statistically significant differences between the three media for causal (F(2, 57) = .62, p = .54, η^2 = .02), cause-related (F(2, 57) = .49 , p = .62, η^2 = .02), incorrect (F(2, 57) = .23, p = .80, η^2 = .01), hypothetical (*Welch's* F(2, 36.57) = 2.83, p = .07, η^2= .07) and redundant justifications (*Welch's* F(2, 36.72) = 1.31, p = .28, η^2 = .04) regarding possible events. Furthermore, there were no statistically significant differences on impossible events for causal (F(2, 57) = 2.38, p = .10, η^2 = .08), cause-related (*Welch's* F(2, 36.33) = 1.03, p = .37, η^2 = .05), incorrect (F(2, 57) = .63, p = .54, η^2 = .02), hypothetical ($F(2, 57) = 1.11$, $p = .34$, $\eta^2 = .04$) and redundant justifications ($F(2, 57) = .11$, $p = .89$, $\eta^2 = .00$) (see Table 4).

Discussion

The aim of this study was to investigate and compare the effects of low-fidelity VR to traditional media (i.e. videos and a picture book) on four-year old children's possibility judgments as well as justifications. Children in the VR group were significantly more likely to correctly judge the possibility of possible events and to incorrectly judge the possibility of impossible events than children in the video group. There were no differences between the picture book group and the other two groups. Furthermore, children in the VR group were more likely to correctly judge the possibility of possible events compared to impossible events. However, there was no difference for children in the other two groups. Moreover, children in the VR group provided significantly more correct judgments than would be expected by chance for possible events and significantly more incorrect judgements than would be expected by chance for impossible events. In contrast, children in both the picture book and video groups judged the possibility of both possible and impossible events at chance-level. In line with our hypothesis and previous research on picture books (Shtulman & Carey, 2007) and videos (Li et al. 2015), four-year-olds used similar justifications for their judgments across all three media and the majority of their justifications were incorrect, hypothetical, or redundant. Therefore, existing differences in possibility judgments between the assessed media appear to be relatively independent from children's reasoning skills, as they tend to rely more on intuition than knowledge.

The finding of a significant difference in possibility judgments between the VR group and the video group is consistent with media richness theory and supports Bailey and Bailenson's (2017) argument that young children may be more easily manipulated to believe in the impossible when using rich compared to lean media. Therefore, VR may have led to children's increased belief that all events were possible. Unfortunately, media richness theory cannot explain why there was no difference between the picture book group and the other two groups in judging the possibility of events, as it was predicted that children in the picture book group would make the least number of incorrect judgments for impossible events.

An alternative explanation for our findings is related to children's inexperience with VR. Indeed, it takes time and experience to learn the conventions of new media and Shapiro and McDonald (1992) suggest that individuals are more likely to be influenced by media information when they have little experience of the media and topic. Therefore, children's lack of experience with VR could explain why there was a difference between the VR group and the video group whereas no difference existed between the other two groups. However, children's inexperience with VR can also not explain why in both the picture book and video groups children judged the possibility of events at chance-level. Indeed, previous research suggested that children correctly judge the possibility of events at a much higher level, especially in the picture book group. For example, Shulman and Carey (2007) found that children correctly judged 91% of possible events and 93% of impossible events in a picture book.

The low level of correct judgements in the present study could be explained by the difficulty of the used events, which were based on the three most difficult fictional events in Li and colleagues' (2015) study. Children are more likely to be confused by unconventional or novel events, such as the ones presented in the current study, because they base their judgments on what normally happens in real life (Shulman & Carey, 2007). Therefore, the difficulty of the chosen events could explain why children performed at chance level in the video and picture book groups. It could indicate that children’s possibility judgements in the video group were not significantly different to the picture book group, in contrast to predictions of media richness theory, because children’s performance was generally so low that it was difficult to distinguish between the two media.

Therefore, we suggest that the present study’s findings can be explained by a combination of the above-proposed hypotheses. Further research is needed to replicate these findings and to investigate whether they represent a short-term transient effect due to the novelty of the technology or more long-term effects due to the nature of the technology.

Limitations and Strengths

The main limitation of the current study, as discussed above, was the children’s lack of experience with VR and its design would have been improved if participants had equal experience of all three media. However, at the time of conducting this study, recruiting pre-school children with VR-experience was difficult due to the low availability of VR-equipment for this age group and a consequently low prevalence of VR-use. From another perspective, this limitation makes the present study interesting, as it demonstrates the impact of a new media on children’s possibility judgments. It is possible that in the future a similar study might not be possible if VR becomes more popular and more universal.

Another limitation was the study’s relatively low ecological validity. Children frequently co-view media under relaxed circumstances in the presence of caregivers. Connell, Lauricella, & Wartella (2015) reported that children often engaged with various media (i.e. books, TV, smartphones, tablets, and computers) with their parents, although co-viewing was less frequent for some media (e.g. video games). Co-viewing can provide children with symbolic insights into the commonalities between media and the real world (Troseth, Russo & Strouse, 2016). Through social interaction and cues, such as eye contact, intonation, background information, previous informant reliability, and a story context, children are further provided with information on possibility, which may help them with their judgments (Woolley & Ghossainy, 2013). For example, children learnt more from the television show "Sesame Street" if an adult introduced content as informative rather than fun (Bonus & Mares, 2015). Additionally, when provided with information on food, children were more likely to distrust an adult who had previously told them inaccurate information (Nguyen, Gordon, Chevalier & Girgis, 2015). Furthermore, children's possibility judgments improved significantly when a guardian engaged them in discussions about possible and impossible events beforehand (Nolan-Reyes, Callanan & Haigh, 2016). In contrast, in the current study, children answered questions to an unfamiliar researcher in an isolated activities room and were not provided with the guidance and context in which they typically experience media.

Nevertheless, this study's method resulted in a high internal validity. For example, it benefited from a naturalistic setting and structured interviewing, which were necessary to control for extraneous variables and order effects. Furthermore, the matching of possible and impossible events within and across media allowed control of the effects of characters as well as event length and content on children's possibility judgments. Some control of the effects of previous education on children's judgments was also afforded, as all children in this study were from the same preschool.

Future Directions

Future work could explore the impact of VR fidelity on children's judgements of the possibility of events. We used the Google Cardboard, which is a low-fidelity head-mounted display (HMD). Although it has a field of view of approximately 90-degrees, which resembles other VR-equipment, it only has three degrees of freedom (DoF).

Therefore, it enables users to look up/down, left/right, and ahead/behind. However, with the Google Cardboard, users cannot move around a scene or interact with virtual content. In contrast, interaction and movement are possible in higher-fidelity VR experiences, for example with the Oculus Rift DK2, which involves six Dof. It is important to distinguish between immersion and presence. Presence can be defined as the psychological experience of ‘being there’, while immersion is related to a medium’s technological quality (Cummings & Baillenson, 2016), low-fidelity HMDs are often considered less immersive than 6 DoF experiences. Theoretical models of presence assume that the greater the immersion, the greater the sense of presence (Wirth et al., 2007), and research tends to support this assumption (Cummings and Bailenson, 2016). In particular, research has reported that the greater the DoF and the wider the field of view, the greater the experienced presence (Cummings and Bailenson, 2016). However, interestingly, fidelity has not been found to influence the effectiveness of VR on learning (Buttussi & Chittaro, 2018, Diaz et al., 2019). Therefore, it is possible that fidelity may influence children’s sense of presence but not influence children’s judgments of possibility.

Moreover, highly immersive and low-immersive VR experiences could be compared for an investigation into the effects of varying levels of presence on children’s judgments. Furthermore, researchers could explore the role of presence for children’s possibility judgements in VR by collecting event-related potential (ERP) data via electroencephalography (EEG) and correlate it to their possibility judgments. Kober and Neuper (2012) showed that individuals who felt present in VR had decreased late negative slow wave amplitudes in response to VR-irrelevant tones due to their increased attention to VR content. Thus, the role of presence in children’s possibility judgements could be explored by investigating the relationship between children’s possibility judgements and late negative slow wave amplitudes during VR-exposure.

Implications

Accepting the limitations of the study, the findings suggest a number of important consequences of VR for young children in terms of shaping their perceptions and understanding. They show that VR may have a stronger influence on children’s understanding of the world compared to other forms of media, which is consistent with previous research. For instance, Bailey and colleagues (2019) found that young children performed worse on an inhibitory control task and showed higher levels of social compliance with VR than with television. Furthermore, Bonus and Mares (2015) report that children who view media content as real are more likely to transfer it to other contexts. Therefore, as Bailey and colleagues (2019) suggest, VR could provide a more effective and powerful medium for young children’s learning than other media.

The same power of VR for influencing children’s understanding and behaviour also presents a number of challenges. They suggest that teachers and parents should ideally co-experience media, particularly VR, with children to provide cognitive support, clarify the media’s real-world applicability, and engage children in discussions to foster their reasoning, justification, and judgment skills (Troseth, Russo & Strouse, 2016). Additionally, this study suggests that highly rich media portrayals could have a strong influence on children’s construction and reconstruction of information. Therefore, media companies are advised to include and maintain where applicable age-dependent warnings of VR, as young children seem highly vulnerable to manipulation when using this medium. However, more research is needed to replicate this study’s findings and determine whether children can reliably judge the possibility of events in VR with experience and, if so, at what age to guide regulations.

Conclusion

In conclusion, this study is one of the first to investigate the effect of VR on young children's judgments of the possibility of events. We found that a low-fidelity VR HMD in the form of the Google Cardboard increased children's tendency to believe that impossible events are possible more than traditional videos. On one hand, our findings show the potential benefits of using VR to support children's learning. On the other hand, they raise concerns about the use of VR by young children without adult supervision, although more research is required to extend and replicate this study.

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Figure 1. Impossible event of two men floating, viewed from above the sofa sitting area.

Table 1. Cues related to media richness of picturebooks, videos, VR and real life (from lean to rich media).

		Media Richness Features		
Media	**Rapid Feedback**	**Multiple Cues**	**Natural language variety**	**Personal Focus**
Picture Books	Content does not respond to the individual	1) Visual: Static Images and Text 2) Possibly Audio: Reading text aloud	1) Spoken/written words 2) Limited body language in pictures including humans	Content is not tailored to the individual.
Videos	Content does not respond to the individual	1) Visual: Animations (Multiple images in quick succession) 2) Audio: Speech, music, sound effects	1) Spoken/written words 2) Sounds/music 3) Body language in videos with humans (gestures)	Content is not tailored to the individual.
Non-interactive Virtual Reality	Virtual environment is updated dynamically based on head movement	1) Visual: Dynamic animations 2) Audio: Speech, music, sound effects	1) Spoken /written words 2) Sounds/music 3) Body language of avatars	Situational awareness (user exists within virtual scene)

				Personalised experience (environment responds to the individual's head movement)
Mental Imagery	Individual's mental image(s) respond immediately to their thoughts	The individual can imagine something based on its: 1) Visuals 2) Audio 3) Smells 4) Tastes 5) Touch/Feel	1) Imagined spoken/written words 2) Imagined sounds/music 3) Imagined body language	1) Situational awareness (user and their experience exist within their own imagination) 2) Personal experience (control and creation of own imagination/ mental imagery)
Reality	Immediate visual, auditory, olfactory, gustatory, haptic and proprioceptive feedback (e.g. sense of space updates with movement)	1) Visual: Dynamic and live images 2) Audio: Speech, sounds 3) Olfactory: smells 4) Gustatory: tastes 5) Haptic: touch	1) Spoken/ written words 2) Sounds/music 3) Body language	1) Situational awareness 2) Personal experience (Live experiences are subjective to each individual)

Table 2. Children's justification types.

Justification Type	**Definition**
Causal	Children referenced scientific truths, explaining the cause of a possible event or facts precluding an event's occurrence. *E.g.: "Two men couldn't float because people are too heavy."*
Cause-related	Children referenced the cause to why an event could/could not happen without directly acknowledging the scientific (physical or biological) reasons behind its (impossible) occurrence. *E.g.: "You can't change colour with a feather, because feathers come from birds and have no other purpose."*
Hypothetical	Hypothetical justifications were less epistemologically sound than factual justifications. They differed linguistically through referencing conditional verbs and conceptually, as they did not answer the question as to why an event was impossible/possible. *E.g.: "Two men could float if they were in space."*
Redundant	Children provided no information beyond what was already discernible from their initial judgment and indicated a lack of understanding or unwillingness to answer the question. *E.g.: "I don't know/It can't happen"*
Incorrect	Incorrect justifications were linguistically similar to causal and cause-related facts. However, they differed conceptually, as they demonstrated a distorted understanding of the world through made-up/inappropriate explanations. *E.g.: "Girls can make others stand still with light because girls are fairies and their lights are magical."*

Table 3. Mean number of correct possibility judgments per event type for each medium.

	M (SD)		
Event Type	VR	Video	Picture book
Possible	2.45 (.89) [a, 1]	1.35 (1.27) [a]	1.80 (1.11)
Impossible	.85 (1.14) [b, 1]	1.90 (1.17) [b]	1.65 (1.18)

Note. *M* = Mean, *SD* = standard deviation. Within rows, means followed by the same letter are significantly different. Within columns, means followed by the same number are significantly different.

Table 4. Mean frequency of Children's Use of each Justification Type for Possible and Impossible Events.

	M *(SD)*					
	Possible Events			*Impossible Events*		
Justification Type	VR	Video	Picture book	VR	Video	Picture book
Causal	.10 (.31)	.20 (.52)	.25 (.44)	.00 (.00)	.20 (.41)	.20 (.41)
Cause-related	.45 (.69)	.35 (.67)	.25 (.55)	.15 (.37)	.40 (.68)	.20 (.41)
Hypothetical	.25 (.72)	.80 (.95)	.80 (1.15)	.40 (.82)	.70 (1.17)	.95 (1.43)
Redundant	1.90 (.91)	1.95 (1.43)	1.40 (1.19)	1.45 (1.23)	1.40 (1.27)	1.60(1.60)
Incorrect	1.15(1.18)	1.50 (1.57)	1.35 (2.06)	1.70 (1.03)	1.40 (1.47)	1.25 (1.33)